

Advanced Vehicle Technologies

Utah Debate Conference
2006

Glade Sowards
Utah Division of Air Quality



Why advanced vehicle technologies?

- ❑ Fuel economy/cost savings
- ❑ Energy security
- ❑ Air quality
- ❑ Reducing greenhouse gas emissions
- ❑ Enhanced performance attributes

Overview

- ❑ Battery electric vehicles
- ❑ Hybrid vehicles
- ❑ Advanced internal combustion engines

Electric vehicles



Battery electric vehicles (BEVs)

□ Pros:

- Clean at point of end-use
- Allows fuel diversification
- High torque
- Enhanced stability control/steering options
- Reduced mechanical complexity

□ Cons:

- Slow
- Poor range: 30-120 miles
- Excessive charging times: 8-10 hours
- Only as clean as the generation source: Electricity may be generated from coal



BEVs: Not *quite* dead yet...



- ❑ Lithium-ion battery technology may help BEVs
 - Similar to laptop, cell phone batteries
- ❑ Three BEVs that use Li-ion batteries:
 - tzero: 0-60 mph in 3.6 seconds; 300 mile range
 - Eliica: 248 mph
 - Venturi: 0-50 in 5 seconds; 200 mile range

Enhanced lithium-ion batteries

- ❑ New batteries using nano-technology
 - 1/5 weight of current batteries
 - Almost fully charged in 5 minutes
 - Longer service life (up to 10x)
 - Safer
 - Used in new power tools like cordless drills
- ❑ Mitsubishi and Subaru are developing BEVs for Japanese market



Fuel cell electric vehicles (FCEVs)

- ❑ Similar to BEV
- ❑ Uses different technologies for storing and processing energy
 - Fuel is hydrogen
 - Stored in a tank
 - Converted to electricity via the fuel cell
 - Fuel cell invented in 1839
 - Forward power provided by electric motors similar to BEVs



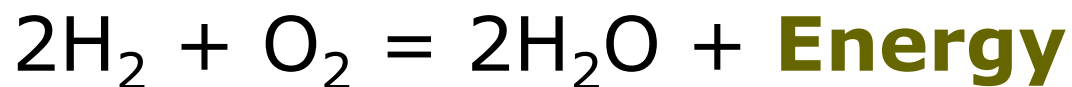
Hydrogen: The perfect fuel?

- ❑ Hydrogen is the most abundant element in the universe
- ❑ Two-thirds of the Earth's surface is covered by water: H_2O
- ❑ Fossil fuels also contain hydrogen
- ❑ Burns cleanly in an internal combustion engine
- ❑ Can be used in a FCEV
- ❑ Problem solved, right?



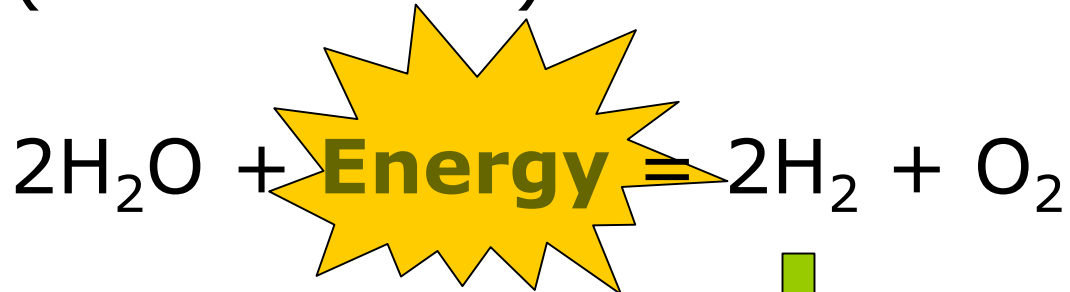
Hydrogen chemistry lesson

The following reaction gives off energy in the form of heat (*exothermic*):



You need energy to get hydrogen...

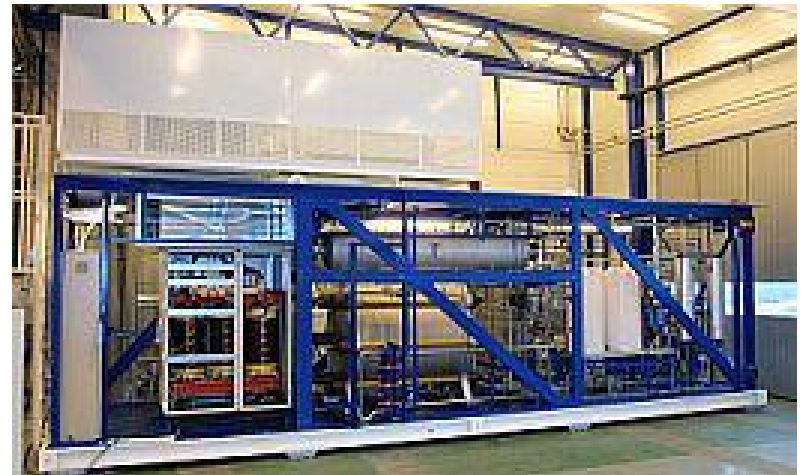
Unfortunately, to get hydrogen from water for fuel, the equation works in reverse (*endothermic*):



Fuel cell car

Using hydrogen in FCEVs?

- ❑ Hydrogen is simply a storage medium
- ❑ Must be released from water or fossil fuels - requires energy
 - Expensive: \$4/gallon
- ❑ Doesn't solve greenhouse gas problem unless from renewables
 - Really expensive: \$7-15/gallon
- ❑ Difficult to transport and store



FCEV limitations

- ❑ Forecast for FCEVs: not until 2025 or later!
- ❑ Several technological hurdles
 - On-board storage
 - Range
 - Durability
 - Cold start capability
- ❑ Current fuel cell vehicles cost \$1-2 million per car or more!

FCEV quotes:

- ❑ When will fuel cell cars replace gasoline-powered cars?: “If I told you never, would you be upset?” – Bill Reinert, Toyota, January 2005
- ❑ “The total time to noticeable impact is likely to be more than 50 years.” – MIT, July 2005
- ❑ “We have a way to go before we can make fuel cells commercially viable.” – Noordin Nanji, Ballard Power, January 2006

Hybrid vehicles



Question: Which vehicle is a hybrid vehicle?



Answer: All of them!



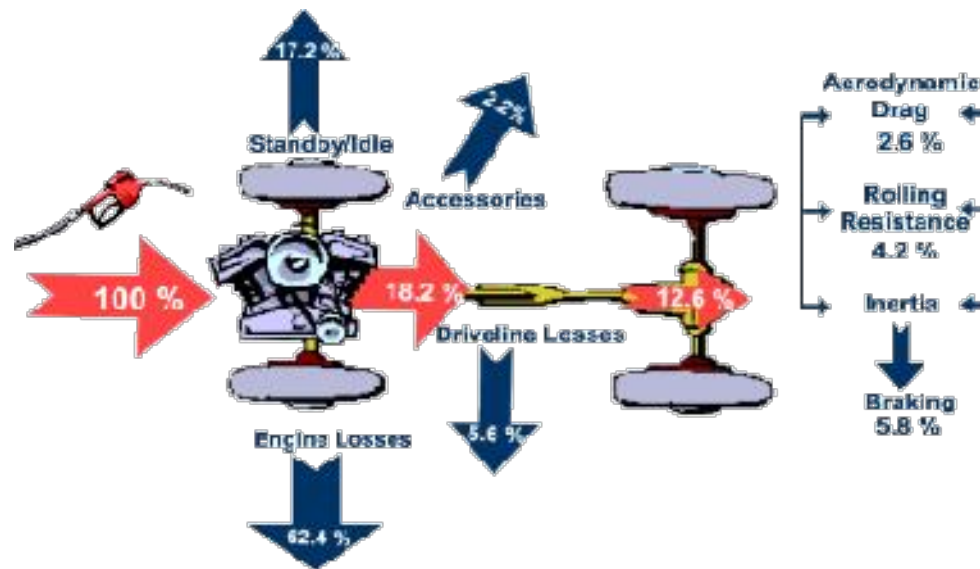
Hybrid vehicles

- Hybrid Electric Vehicles (HEVs)
- Fuel Cell Hybrid Vehicles (FCHV)
 - Most FCEV designs utilize hybridization
- Hydraulic Hybrids
- Flywheel Hybrids



Hybrids and vehicle energy use

- Hybrid “smooth out” a vehicle’s driving cycle
 - Energy is saved when there’s some to spare
 - Used when extra power is needed



Like riding a bicycle...



It's harder to get a bike going than to keep it going.



It's also harder to ride up a hill than on level ground.



It's easy to coast down a hill...
You might even want to use your brakes!

Like riding a bicycle...



It's harder to get a bike going than to keep it going.

Boost!



It's also harder to ride up a hill than on level ground.

Boost!



It's easy to coast down a hill...
You might even want to use your brakes!

Save!

Hybrid electric vehicles (HEVs)

- HEVs typically consist of a combination technologies:
 - Off-at-idle/enhanced alternator-starter motor
 - Battery or ultra-capacitor
 - Electric motors
 - Thermal storage
 - Electric power steering
 - Electric air conditioning compressor
 - Cylinder deactivation
 - Atkinson cycle/Miller cycle engine

HEV designs

□ **Series**

- ICE runs generator
- Motors turn wheels
- No mechanical transmission

□ **Parallel**

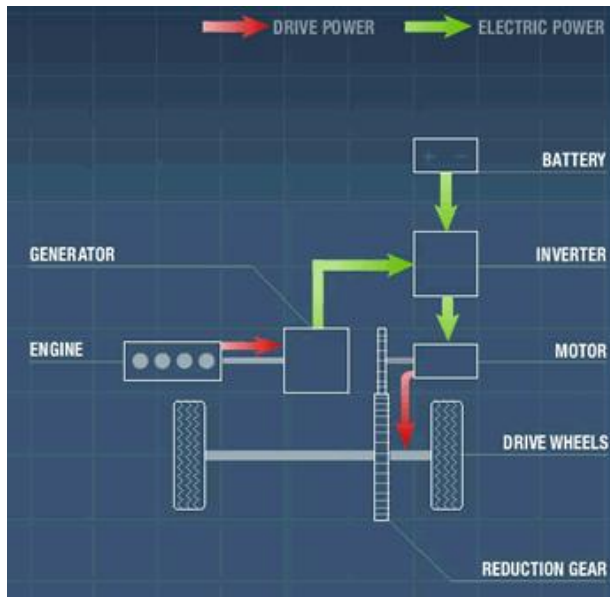
- Motors help ICE via mechanical transmission
- Can't run on motors alone

□ **Series/Parallel**

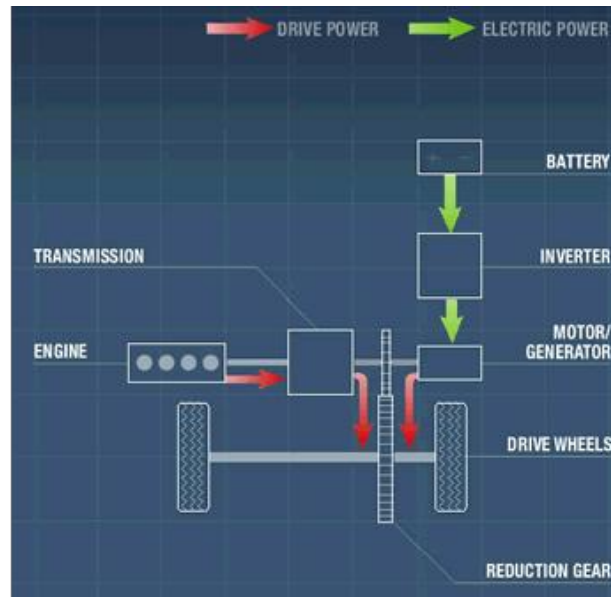
- Varying amounts of power supplied by ICE, motors or both
- Can run in electric-only mode

HEV designs

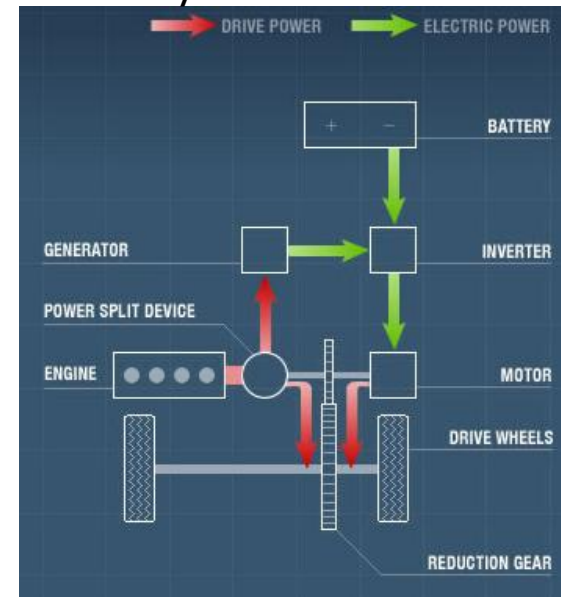
Series



Parallel



Series/Parallel



Other HEVs

❑ Diesel-electric HEVs

- Combines high-efficiency of diesel engines with HEV components
- Problem: additional expense for both diesel and HEV systems

❑ Plug-in HEVs

- Can charge from electricity grid
- Allows short electric-only range (~20-30 miles)
- Long-range trips possible using gasoline engine
- Problem: larger battery is very expensive

Current HEVs: 10 models

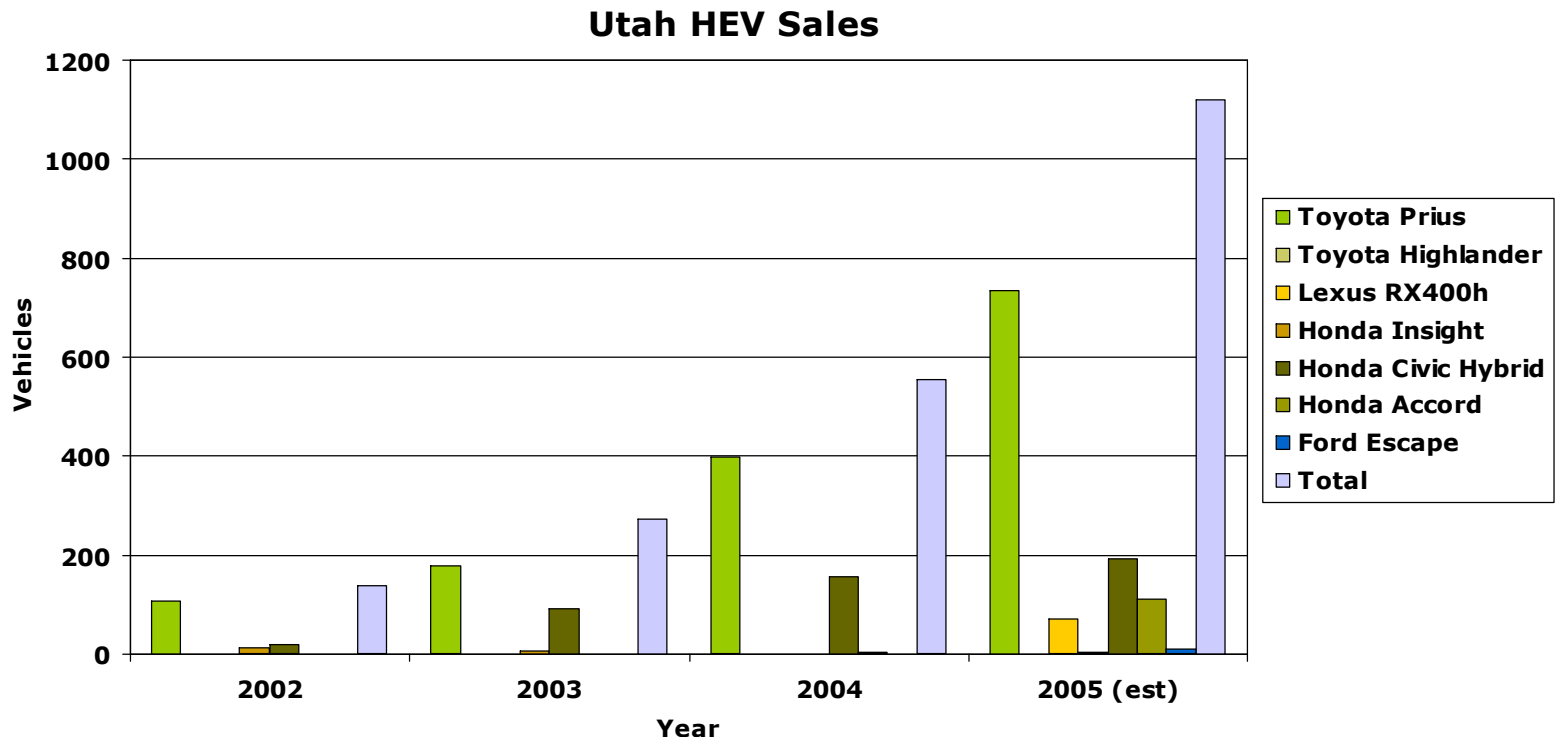
Model	Make	City	Highway
Insight (manual)	Honda	60	66
Civic	Honda	49	51
Accord	Honda	29	37
Prius	Toyota	60	51
Highlander (AWD)	Toyota	31	27
RX400h (AWD)	Lexus	31	27
Escape (AWD)	Ford	33	29
Mariner (AWD)	Mercury	33	29
Silverado (4wd)	Chevy	17	19
Sierra (4wd)	GMC	17	19

Future HEVs: 2006-2010

Model	Make
Lexus GS (spring 2006)	Lexus
Lexus LS (2007)	Lexus
Camry (spring 2006)	Toyota
Altima	Nissan
Vue (summer 2006)	Saturn
Tahoe/Yukon (2008)	Chevy/GMC
Fusion/500	Ford
Malibu	Chevy
Escalade	Cadillac
Tacoma or Tundra	Toyota
Equinox	Chevy
Durango	Dodge
Jetta	Volkswagen
Rio	Kia
Accent	Hyundai
X-3	BMW
Tribute	Mazda
Subaru	Subaru
Porsche	Porsche
Mercedes	Mercedes

HEV sales

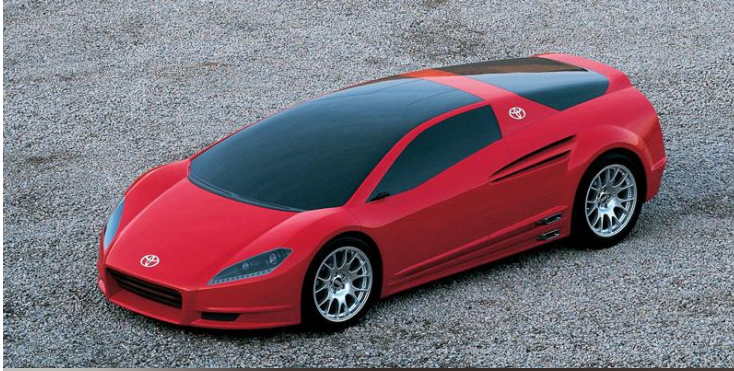
- ❑ 176,500 HEVs sold nationally in 2005
- ❑ 780,000 HEVs sold annually by 2012
- ❑ Over 1,100 sold in Utah in 2005
 - Sales have nearly doubled each year!
 - Still a small fraction (1%) of cars sold in Utah annually



HEV incentives

- ❑ Federal
 - Federal tax credit
- ❑ State
 - No state tax credit for HEVs
 - Single-occupant HOV lane access... might change!
- ❑ City
 - Free parking in downtown SLC
- ❑ Private
 - Travelers Insurance – 10% discount
 - ❑ HEV drivers have been involved in fewer accidents

HEVs: Slow, gutless, boring, impractical?



- Toyota Alessandro Volta Hybrid Concept: 0-60 mph in 4 seconds
- BMW X3 Hybrid: 440 lb-ft of torque
- Lexus LS hybrid: >380hp
- Toyota is planning a V-8 full-sized hybrid pickup



HEV pros and cons

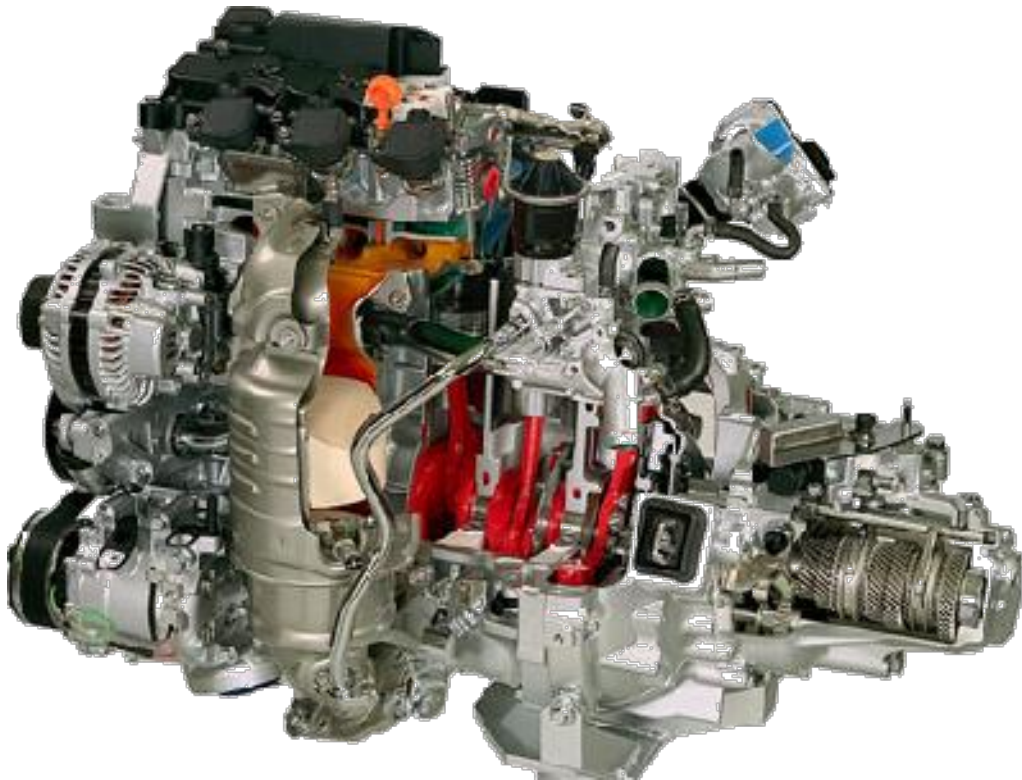
□ Pros:

- Increased fuel economy
- Lower emissions
- Can reduce *mechanical* complexity
- Can provide smoother acceleration

□ Cons:

- Expensive (difficult to recoup costs)
- Can increase *overall* complexity
- Unproven battery life
- Don't always achieve EPA mpg ratings

Advanced internal combustion engines



Clean diesels: What??!

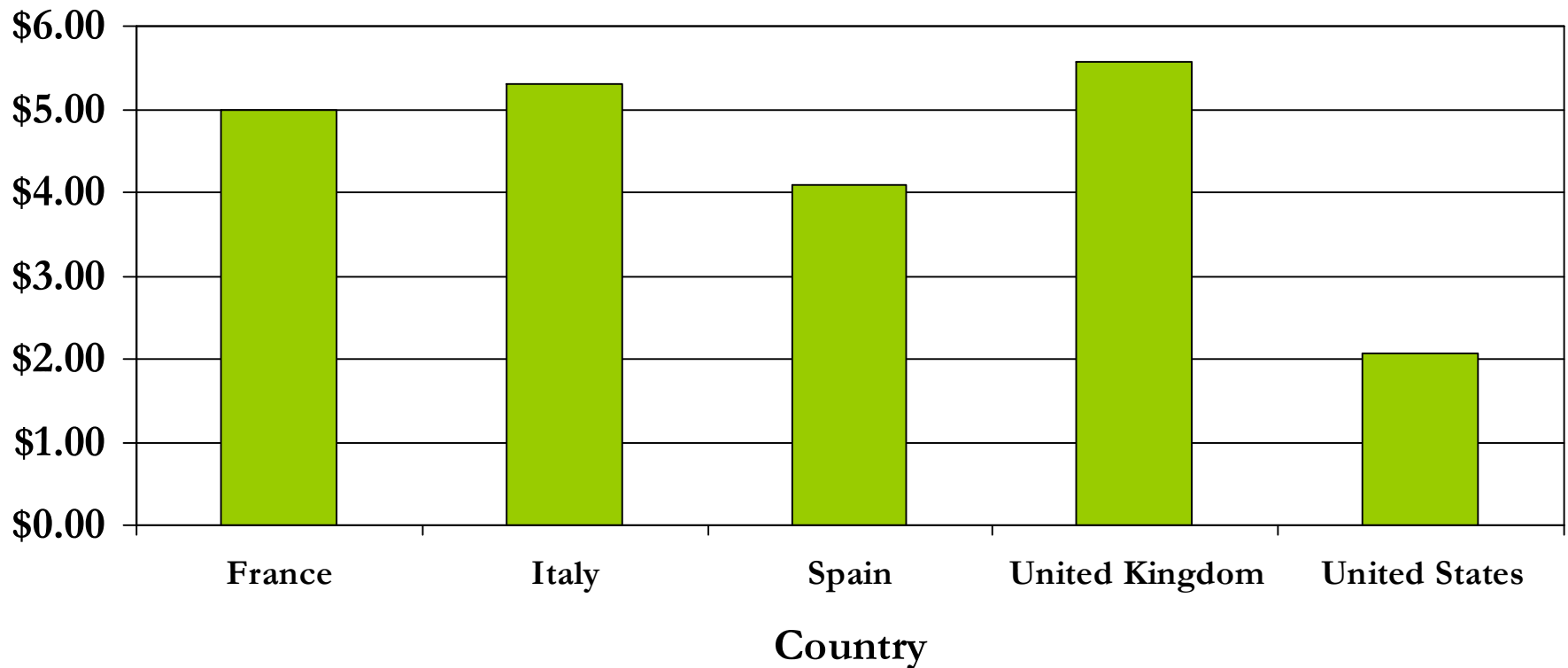
- ❑ Diesels are extremely efficient
 - 30-50 percent improvement in efficiency
 - Lower greenhouse gas emissions
- ❑ Over 50 percent of new cars sold in Europe are diesels
 - European diesel fuel is lower in sulfur
 - Allows for better exhaust treatment technologies



The 2006 VW New Beetle TDI can achieve 44 mpg on the highway (compared to 32 mpg for gasoline version)

Why does Europe like efficient diesels?

Gasoline Prices by Country (\$/gallon)



Ultra-low sulfur diesel in fall 2006

- New diesel emissions controls
 - NOx adsorber/catalyst
 - Diesel particulate filter
 - Diesel oxidation catalyst



New U.S. diesels



- ❑ 2005 Jeep Liberty SUV
 - 25% increase in fuel economy
 - More low-end torque for towing

- ❑ 2005 Mercedes E320 CDI

- 27/37 mpg (city/hwy)
- 600+ miles range
- 2006 "BlueTec" model:
 - ❑ Low Emissions Vehicle
 - ❑ Emissions comparable to gasoline-powered Honda Civic



Other diesels – Coming soon!

- ❑ Mercedes:
 - GL320
 - ML320
 - S320
 - R-class sport wagon
- ❑ Honda
- ❑ BMW
- ❑ Nissan
 - Titan, Armada, Infiniti QX56
- ❑ Chrysler
 - Jeep Grand Cherokee
- ❑ Toyota
 - Tundra

High-mileage diesels



- VW 3-litre Lupo
 - Four seats
 - 78 mpg
 - Available currently in Europe

High-mileage diesels



- VW 1-litre car (experimental)
 - Small diesel engine
 - Composite body
 - Advanced aerodynamics
 - **235 mpg!!!**

Partial Zero-emission Vehicle (PZEV)

- ❑ PZEVs are nearly as clean as traditional AFVs
- ❑ PZEV available on the Ford Focus as a \$115 option
 - Emits just 1 pound of smog-forming emissions over 15,000
 - Normal Focus emits 10.7 pounds
- ❑ Exhaust can actually be cleaner than intake air!
- ❑ Runs on regular unleaded gasoline



Available PZEVs

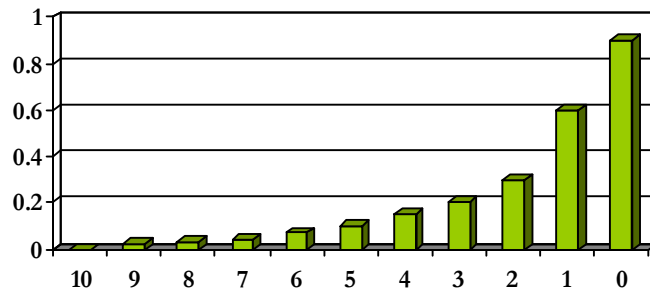
- ❑ BMW 325i Coupe, Sedan, Wagon
- ❑ Ford Focus Hatchback, Sedan, Wagon
- ❑ Honda Accord Sedan
- ❑ Hyundai Elantra
- ❑ Mazda3
- ❑ Mitsubishi Galant
- ❑ Nissan Altima
- ❑ Nissan Sentra
- ❑ Subaru Legacy/Outback Sedan and Wagon
- ❑ Toyota Camry
- ❑ VW Jetta Sedan
- ❑ Volvo S60
- ❑ Volvo V70

Other technologies

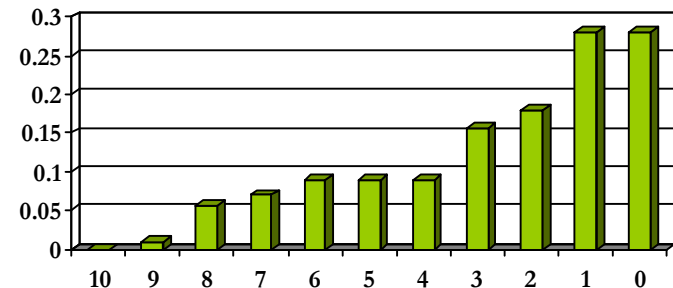
- ❑ Variable valve timing
- ❑ Cylinder deactivation
- ❑ Advanced injection and combustion technology
- ❑ Weight reduction/use of composites
- ❑ Advanced aerodynamics
- ❑ Variable geometry turbocharger (VGT)
- ❑ Continuously variable transmissions (CVTs)

EPA emissions score*

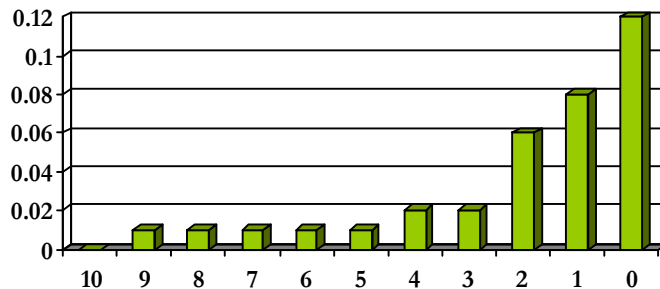
NO_x



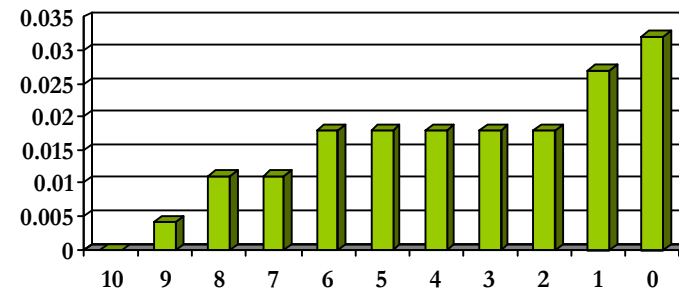
NMOG



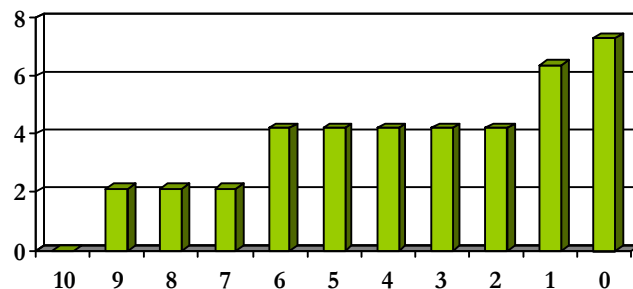
PM



HCHO



CO



Examples:

Honda Natural Gas: 9.5

Honda HEV: 9.5

Prius HEV: 9.5

Ford Focus PZEV: 9.5

Honda Civic: 6

'07 Mercedes Diesel: 6

'06 VW Jetta TDI: 1

*Max. allowed grams/mile

Which technology?

Vehicle	\$/mile*	Total Cost*
'06 Camry (gasoline)	\$0.51	\$38,326
'06 Prius (HEV)	\$0.51	\$38,385
'06 Jetta TDI (diesel)	\$0.49	\$36,924
'03 Camry (used gasoline)	\$0.40	\$30,353
'06 Corolla (gasoline)	\$0.37	\$27,488

*Source: Edmunds

Why not a Super-Hybrid or Franken-Car?



Why not a Super-Hybrid or Franken-Car?



Why not a Super-Hybrid or Franken-Car?



Cost is important!

Technology	Cost	Pollution Reduced (pounds)	\$/pound
A	\$50	2	\$25
B	\$500	25	\$20
C	\$1000	30	\$33.33

If I only have \$1,000 to spend, which technology reduces the most pollution?

Cost is important!

Technology	Cost	Pollution Reduced (pounds)	\$/pound
A	\$50	2	\$25
B	\$500	25	\$20
C	\$1000	30	\$33.33

If I only have \$1,000 to spend, which technology reduces the most pollution?

- C gives me 30 pounds reduced
- A gives me 40 pounds reduced
- **B gives me 50 pounds reduced**

Top secret research links:

- ❑ US Dept. of Energy Fuel Economy:
 - www.fueleconomy.gov
- ❑ US Dept. of Energy Data:
 - www.eia.doe.gov
- ❑ EPA Green Vehicle Guide:
 - www.epa.gov/greenvehicles
- ❑ Utah State Energy Program Energy Data:
 - <http://geology.utah.gov/sep/newdata/statpage.htm>
- ❑ Green Car Congress:
 - www.greencarcongress.com
- ❑ Electric Vehicle World:
 - www.evworld.com

TOP SECRET!!!

Questions or comments?